Window Glass in the Making

by

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Pittsburgh, Pa. U.S.A.

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An Art, A Craft, A Business

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FOREWORD

If the world were deprived of window glass today, civilization would be turned back at least 500 years. Without it we would be compelled to forego many of the conveniences, comforts, and luxuries of modern life and would revert to the inconveniences, the discomforts, and the hardships of medieval times.

No matter where we go or what we do, we are confronted by the ever-increasing uses of window glass. In fact, it is in such general use that probably none of us, except those closely allied with the production of window glass, has any appreciation of its importance or realizes how essential it is, and has been, to the progress of mankind.

It is the purpose of this book to tell enough about window glass to give architects, dealers, contractors, home-builders, and all other users a better understanding of its nature and characteristics, in order to render them more competent to judge the quality. With this knowledge they will demand "The Best Glass" obtainable and will refuse to accept glass of inferior quality, especially when paying for the better article. This knowledge is not only of interest but of great value to every user of window glass.

Such information has not been available heretofore in books or other publications, for there is practically no literature on the subject of window glass.

During years of study and experimental work in the development of a new process of manufacturing window glass, and by the expenditure of millions of dollars in bringing that process to complete commercial success, we acquired a comprehensive understanding of it that could not be gained in any other manner.

Yet we realize that there is much we do not know about it. In that respect we differ from what the renowned, and probably the most learned man of his time, Professor Jowett, of Baliol College, was reported to have said, "All that known is, I know it; what I know not is not knowledge."

To acquaint the reader with much of the knowledge that we have acquired, it is our intention to define window glass; to point out the variety of its uses in order to show how they are affected by the quality; and to explain what is meant by the term, "quality." This will be followed by an account of the origin of glass for its bearing on the composition.

We shall then describe briefly our process of manufacturing window glass, by tracing the raw materials of which it is made through the different

steps of the process until they finally appear in the form of flat sheets of clear glass, ready for use.

However, it is not the intention to go into a technical description of the process of manufacture, such as will interest only the trained chemist or the glass engineer, but to describe it in such a manner as will interest those who desire to add to their fund of useful information, and those who have not the time to give to a highly technical exposition of the subject.

For the benefit of those who desire a more complete commercial knowledge of window glass, its various thicknesses and qualities, with the rules for grading, and the method of glazing, an Appendix is added, wherein is set forth an exact copy of the "U. S. Government Master Specification for Flat Glass for Glazing Purposes," so far as it relates to window glass, with our notes and comments thereon.

The Appendix also sets forth the fourteen reasons why our glass is "The Best Glass."

American Window Glass Company

DEFINITION OF WINDOW GLASS

USUALLY we think of window glass as a hard, clear, brittle substance, and do not realize that, at a sufficiently high temperature, it becomes a liquid. When cold, it has great tensile strength and elasticity. Everyone who played marbles, when a child, had his favorite "glassie," that could be used only because of that elasticity.

Glass is a poor conductor of heat. One end of a short rod of glass can be held in the bare hand without discomfort while the other end is being melted in a furnace.

The chemists say that it is an amorphous substance —that is, having no regular structure; and diaphanous—that is, translucent and transparent. They go further; and say that it is a salt.

No matter how it is defined or described, to convert ordinary sand mixed with a few other ingredients into a bright, clear substance of fine quality, which we call window glass, and which affects so greatly our welfare and happiness, is an art that requires the science of the chemist, the genius of the engineer, and the technique of the artist.

CHAPTER I

USES

WINDOW glass was born of the necessity of mankind in the colder countries for a material that would let in the light and keep out the elements, that would keep in the heat and shut out the cold. Its development has kept pace with the progress of civilization. From the skin tents of the Nomads to the solid doors and shutters in the cabins of the frontiersmen; from the rice paper and oiled parchment in the windows of the Orient to the dazzling brilliance of the crystal palaces of the Occident, we trace its ever-increasing uses.

Today it is in such general use that it has become known as "common window glass." Recognizing this fact, Congress has used this designation in many of the tariff laws.

Not always has it been such a commonplace article. Even as late as the fourteenth century Richard II issued a writ to scour the counties of Norfolk, Northampton, Leicester, and Lincoln, to find glass to repair the windows in the castle at Stamford, built in honor of his mother.

In the sixteenth century, window glass was so

The Skin Tent—
The habitation of many nomadic tribes before glass gave permanence to civilization.

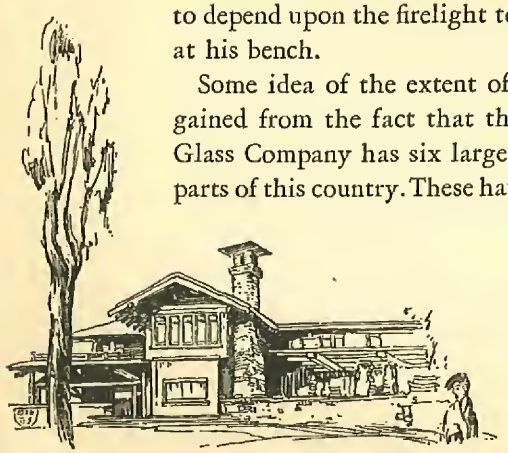
expensive in Germany that the law provided that on the death of the owner of a building, the glass belonged to his executors, but the windows went to the heirs, "for the house is perfect without the glass."

As late as 1686, Sir R. Worsley, writing of his travels, said, "In all ye great towns of Italy, except Genoa, and in this city (Murano), they have paper in their sashes instead of glass."

For centuries it continued to be regarded as a luxury and was taxed accordingly, down to recent times. It is a question whether the "window tax" has been entirely abolished in all European countries to this day.

We see so much window glass and can obtain it so easily and so cheaply that we fail to appreciate its value or the effect it has on our lives. We do not realize how it changes the lives of those who would otherwise be obliged to live in shadows and darkness. Isak, the hardy frontiersman in Knut Hamsun's "Growth of the Soil," found it a bright and wonderful day when he was able to put glass in the windows of his hut. He was no longer obliged to depend upon the firelight to enable him to work at his bench.

Some idea of the extent of its use here may be gained from the fact that the American Window Glass Company has six large factories in different parts of this country. These have the capacity to pro-



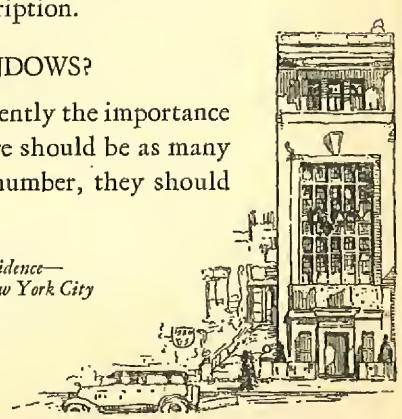
A residence—
Pasadena, California

duce annually about three hundred million square feet, or six million fifty-foot boxes of window glass, which makes this Company "The World's Largest Producer" of window glass. If all this glass were of single thickness, cut 24 inches square, and packed in fifty-foot boxes, and these boxes laid on the ground end to end, they would make a sort of boardwalk extending 2651 miles, or from the Atlantic to the Pacific Coast.

Window glass has an almost endless variety of uses. An enormous quantity is consumed for other purposes than glazing; that is, putting it into window frames. Of course, the largest amount is glazed in windows and doors of houses, schools, churches, colleges, hospitals, hotels, stores, greenhouses, factories, in fact buildings of every kind. Considerable is used in street railway and railroad coaches, in carriages, trucks, and automobiles. Much is used for other articles such as eyeglasses, photographic dry plates, lantern slides, microscopic slides, X-ray plates, vanity cases, toilet articles, pictures, mirrors, showcases, counters, shelving, tops for desks, tables, and for furniture of every description.

WHY USE WINDOWS?

Few people appreciate sufficiently the importance of windows in buildings. There should be as many as possible; but if limited in number, they should



A residence—
New York City

be as large as possible. The old Gothic cathedrals were built with the windows as large as possible, and just enough stonework to support the building.

In factories, workrooms, offices, hospitals, school buildings, and homes, the use of clear window glass to "Let in the Sunlight" is of compelling importance, for with it you let in health and happiness. The sun's rays are nature's greatest purifier, which the medical profession has recognized by using "artificial sunlight" for disinfecting wounds, and for therapeutic treatments.

Careful and exhaustive tests have demonstrated that workers in a factory in which the windows are glazed with clear window glass do better work than those in factories in which obscure glass is used. When at the workbench, the opportunity of "catching a glimpse" of the outside world exerts a psychological effect on the workers. It takes away the feeling of confinement and promotes cheerfulness and contentment. A contented workman always does the best work.

For economical reasons there should be plenty of windows in a building. Window glass costs less per square foot of wall space than lumber, tile, or brick. At the present time, in a modest brick dwelling of average size, the window glass represents less than one-half of one per cent. of the total cost of the building.

CHAPTER II

QUALITY

On account of the varied uses of window glass, its quality is most important, as it affects intimately every user. Very few know what is meant by the term, "Quality," or how it may be determined.

"Quality" in window glass covers not only the chemical composition and physical properties, but also the grade of the glass from the standpoint of defects. It may be of good quality so far as its composition and properties are concerned, but of very poor quality as regards the defects. The differences in composition and properties can only be discovered by analysis and test; but in grading, they can readily be detected by comparing different makes of glass.

Grading is separating the lights, or panes, of glass into different grades or classes of quality, according to the character, size, number, and position of the defects, which affect not only the appearance of the glass itself but of the objects viewed through it. The casual observer notices these defects, but thinks they are inherent in the process of manufacture, and therefore unavoidable. He does not know that they are unnecessary, and that window glass which is

practically free from them may readily be obtained.

A beautiful house showing the care, thought, and artistic sense of the architect who planned it, is often disfigured by the poor quality of the glass he unwittingly permits to be placed in the windows. The enjoyment of one's home is sometimes spoiled by defects in the glass that hinder the vision. Frequently the appearance of a fine picture is ruined by the execrable quality of the glass used in the frame. The pleasure of a ride through an interesting part of the country in a railway coach, street car, or an automobile often is taken away by the poor quality of the glass through which one is obliged to view the scenery. Glass of poor quality not only spoils the view, but offends the eye, and irritates the nerves of one compelled to view continually objects distorted in appearance by its defects.

A very large amount of window glass produced is of such poor quality that it is not fit for commercial use and is really rubbish which should be remelted. Instead of disposing of it in this manner the incapable manufacturers who produce this glass put it on the market at low prices. Notwithstanding its poor quality, such glass is finally used for many purposes for which it is grossly unfit. This would not be possible if more were known about it.

"THE BEST GLASS"

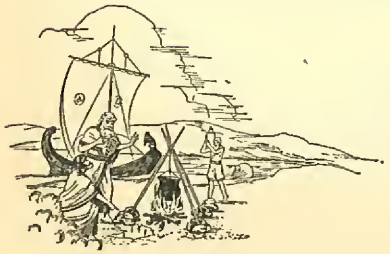
The American Window Glass Company produces a very large quantity of a highly perfected product of beautiful lustre, graded to the highest possible standard and known as "The Best Glass." It is suitable for every purpose. Its production is possible only with a process conducted on scientific principles, by a Company that has built up, after years of effort, an organization of highly skilled employees, who pride themselves on their workmanship as greatly as the Company prides itself on its product. Every user can obtain "The Best Glass" if he insists upon having the American Window Glass Company's brand and is competent to judge the quality of the glass furnished. The price of it is not substantially different from that of glass of inferior quality.

CHAPTER III

GLASS—ITS ORIGIN

THE origin of glass is still in doubt. Many theories have been advanced by ancient and modern writers to explain its discovery, but they can, at most, simply recount what tradition tells. Some writers say that the Egyptians discovered glass; others claim it was a discovery of the Chinese. Probably the most accurate account of its origin, and certainly a very plausible one is that related by C. Pliny the Second in his "History of the World," Volume 36, Chapter 27. According to Pliny, there was in Phoenicia a short river, called Belus, that flowed from Lake Candeboea to the sea. Its waters were muddy and unwholesome, and nothing was to be found on its banks but sand. This had been cast up by the sea, and from frequent washings by the waves was pure and white and suitable for making glass.

One day some traders, who had been gathering a cargo of nitre, sought, along the banks of the river, stones on which to mount a tripod to cook their food. Not finding any, they were obliged to use blocks of nitre taken from their cargo. Under the heat of the fire, the sand coming into contact with

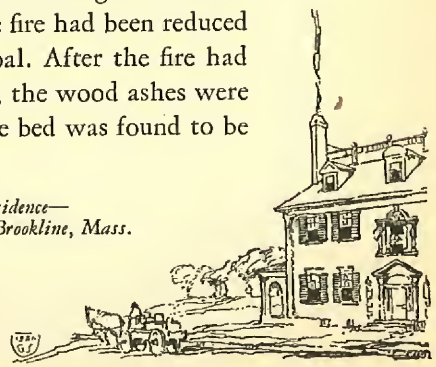


Illustrating the discovery of glass as related by Pliny the Second

the nitre, which acted as a flux, formed a vitreous substance—"glass."

Though there is room to doubt that this is the true account of the origin of glass, there are certain basic features in it that make it appear not only plausible but easily possible. From our later knowledge, we know that sand alone may be fused into a vitreous mass by applying a very high degree of heat; and that by mixing with it a quantity of soda, the temperature required to do this is greatly lessened. By using nitre, which contains a large percentage of soda, these ancient traders used an ingredient that materially lowered the melting point of the sand and made possible its reduction into glass.

To demonstrate the possibility of the discovery of glass in some such manner, we recently caused a wood fire to be made in the open air. Small logs were laid on a bed of glass sand mixed with an equal quantity of carbonate of soda. In order to secure accurate information of the degree of heat that could be obtained from such a fire, a standard pyrometer couple was inserted into the bed, and frequent readings taken. The fire was kept burning about two hours. The highest reading, 2210 degrees Fahrenheit, was obtained when the fire had been reduced to a mass of burning charcoal. After the fire had completely burned itself out, the wood ashes were removed and a portion of the bed was found to be



Residence—
Brookline, Mass.

fused into a vitreous mass—the same kind of glass discovered by the Phoenicians. In a similar demonstration, with a bed of glass sand mixed with an equal quantity of nitre, a like result was obtained; but when a bed of glass sand unmixed with any other ingredients was used and subjected to the same kind of a fire, there was not the slightest trace of any fusing of the sand.

It seems quite plausible, therefore, that glass was first made somewhere along the shore of the sea. Many centuries after Pliny, it was found that when seaweed was burned, its residuum, called "kelp," contained a large amount of carbonate of soda. Subsequently this was used in making glass, and there became known to the trade the term, "kelp glass."

It requires no great stretch of the imagination to think that at some time there had been kindled along a sandy shore a great bonfire of dry seaweed, with perhaps a lot of driftwood, which left amid its charred embers the vitreous mass we now call glass.

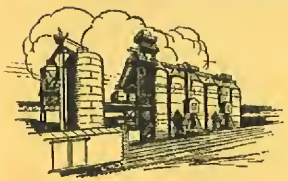
Owing to the impurity of the raw materials and to the cruder methods of manufacture, the glass made by the ancients was not the bright, clear, transparent article in use today, but was much darker and contained many bubbles and foreign particles, which made it more translucent than transparent. Saint Paul refers to this feature when he

A Virginia Plantation House

says, "For now we see through a glass, darkly"—I Cor., xiii, 12.

Centuries elapsed before this discovery by the Phoenicians was put to any practical use. In fact, we may say that glass really had to be rediscovered before glass articles of any kind could be produced. While it is not the intention to go into the history of glass making, the story of its origin is recounted for the bearing it has on the development of the various compositions subsequently used in making window glass.

MIXING RAW MATERIALS



Materials are stored in concrete bins to prevent deterioration

CHAPTER IV

COMPOSITION

ORIGINALLY, the composition of glass was a great secret, known only to the alchemists, who guarded it with jealous care. Subsequently, some knowledge of the ingredients and their proportions spread to others, who put it to practical use; but all of these early manufacturers guarded with care the secret of their formulas. This is proven by the evident lack of exact information shown by the old writers from the time of Agricola, A. D. 1556. This secrecy has been maintained by glassmakers down through the centuries and continues to a considerable extent to the present time. Today, very few will disclose the exact proportions of the materials used in making their glass. They believe that the slight variations they make from time to time in the composition are responsible for producing glass superior in quality to that of their competitors. They seem to be blissfully ignorant of the fact that the chemist of today, by analyzing a small sample of their glass, can quickly solve their closely guarded secret.

Today, window glass is made from silica (sand) mixed either with sulphate of soda (salt cake) or

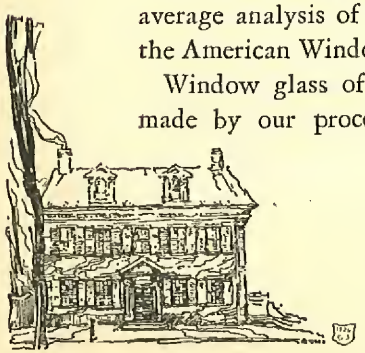
carbonate of soda (soda ash), or with a combination of these two forms of soda. To these ingredients is added lime, either in the form of ground limestone, burnt lime, or dolomite. With sulphate of soda, a small amount of carbon is added, either in the form of crushed coal or coke, or ground charcoal. Sometimes arsenic, manganese, or other decolorizers, in small quantities, are introduced into the mixture, whenever it is desired to obtain glass free from the usual greenish tint which is caused by a small percentage of iron in the materials or in the clay of the pots or blocks of the furnace.

Upon the purity of the materials, their degree of fineness, and the proportion in which they are used, depend the color, quality, toughness or brittleness, and density of the glass produced.

The American Window Glass Company uses the purest materials obtainable, ground to the requisite degree of fineness. They are mixed in certain proportions, determined after years of study and experiment, and produce "The Best Glass" possible, as is shown by every chemical and physical test to which it can be subjected.

The table on the next page represents about an average analysis of the window glass produced by the American Window Glass Company.

Window glass of approximately this analysis, made by our process, will have greater tensile



Old House at Germantown, Pa.

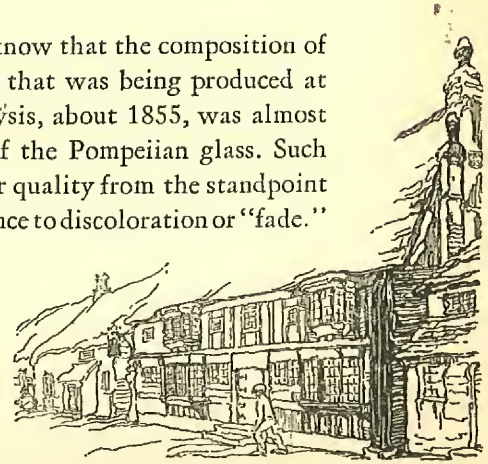
strength, a higher modulus of rupture, and more resistance to the action of moisture than glass having a lower percentage of silica or lime, or a higher percentage of soda:

Silica	73.25%
Lime	12.50
Soda	12.50
Alumina	.75
Other Ingredients	1.00
Total	100.00

An analysis of pieces of glass from windows found in the ruins of Pompeii, which was destroyed in 79 A. D., gave the following result:

Silica	69.45%
Lime	7.24
Soda	17.51
Alumina	5.55
Other Ingredients	.25
Total	100.00

It is interesting to know that the composition of French window glass that was being produced at the date of that analysis, about 1855, was almost identical with that of the Pompeiian glass. Such glass was of very poor quality from the standpoint of strength and resistance to discoloration or "fade."



Windows in Sussex

COMPOSITION OF GLASS MADE BY OTHER PROCESSES

At the present time many factories using some of the other new processes of making window glass require molten glass that can be worked at comparatively low temperatures without devitrification. Devitrification, as its name indicates, is the changing of the glass from a liquid condition into a white, opaque solid that does not have the characteristics of glass. It is usually caused by maintaining the molten glass at too low a temperature, which varies according to the composition of the glass. It begins with the formation of very small crystal-like particles resembling large grains of very white sand or small stones, which cause enormous breakage during the process of manufacture. These gradually become larger and more numerous, until they finally permeate the entire body of glass and change it into a hard white substance resembling porcelain. This is often called "The Porcelain of Réaumur," after the celebrated French physicist who first made a study of this change in the glass. It is interesting to know that if this devitrified mass is subjected to a sufficiently high heat, it will again become liquid glass.

In our process of manufacture, the glass is worked at such a high temperature that it does not devitrify.

This enables us to use a composition that produces glass with the best physical and chemical properties.

To obtain glass that will not readily devitrify at the low temperatures required for those other processes, very important changes are made in the composition, which produce a quality of glass inferior to ours from the chemical and physical standpoints.

The changes are as follows:

1. **The percentage of silica is lowered.** Therefore less heat is required to melt the composition, but the resultant glass does not have the strength or durability of window glass containing a higher percentage of silica.
2. **The percentage of soda is increased.** This enables the composition to be melted at a lower temperature, but makes the glass less dense and more hygroscopic; that is, causes it to sweat more readily.
3. **The percentage of lime is lowered.** Reducing the amount of lime in the composition causes the glass to set, or harden, more slowly and thereby lowers the temperature at which it can be worked without devitrifying. This reduction, however, causes the glass to have less ductility and less body, and increases the tendency of the soda in the glass to attract the humidity of the air; or, in other words, renders it more deliquescent.

As a result of these changes in the composition, the glass produced by those processes analyzes about as follows:

Silica	72.00%
Lime	10.75
Soda	15.50
Alumina	.75
Other Ingredients	1.00
Total	100.00

Glass of the foregoing analysis does not have the same strength or durability as glass that contains the correct proportions of the different ingredients, and it is much more susceptible to attack by moisture. It will therefore lose its brilliance of surface more quickly by discoloring, *i.e.*, fading, staining, or rusting.

CHAPTER V

MELTING AND REFINING

With the raw materials thoroughly mixed in suitable proportions, then comes the melting. Formerly this was done in furnaces built to contain large clay pots in which the composition was melted. In making window glass this system has been entirely superseded in this country by the continuous melting regenerative tank system, which uses either producer gas or natural gas for fuel.

The American Window Glass Company has thirteen continuous glass melting tanks, or furnaces, of the most modern construction, five of which are much larger than any other glass melting furnaces in the world. The largest ones are 30 feet wide, 140 feet long, and 5 feet deep. To visualize a tank of such size, picture an enormous swimming pool with a capacity of 172,627 gallons, filled with 1800 tons of molten glass, varying in temperature from 2200 to 2700 degrees Fahrenheit. If all the glass in one of these large furnaces were made into a light or pane of single strength thickness one foot wide, it would extend for a distance of six hundred miles, or from Pittsburgh to St. Louis.

CHARGING THE FURNACE

Testing Laboratory constantly checking purity of materials

In the modern continuous melting tank system, the raw materials are placed in the furnace along with some broken glass called, "cullet," which facilitates the melting. Then they are exposed to the heat of the furnace in the melting zone until they are entirely reduced to a viscous mass, full of bubbles formed by the gases given off during the melting, which have not yet been able to escape during that process. Additional raw materials are fed into the furnace at regular intervals as rapidly as the preceding charges are melted. The furnace is maintained at the melting temperature continuously for months, and there is no cessation of the melting, the raw materials being fed in at one end, while the molten glass is taken out at the other end, except during the usual Sunday shutdown. This continues until the furnace has been burned out to such an extent as to need repairs.

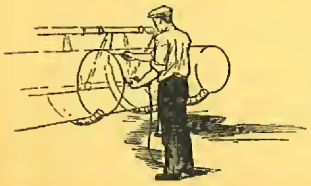
The melted viscous mass of glass moves slowly down the furnace, passing through a hotter zone, which renders the mass still more liquid, and thus allows the pent-up gases to escape. This is the refining process. If the temperature of the refining zone is not high enough, or if the glass passes through it too quickly, the glass will not be properly refined and will contain bubbles of various sizes, some quite large, and some as small as a pin point.

POURING MOLTEN GLASS
(The last step preceding the drawing or blowing process)

Ladle Bosh which cools the ladle after the pouring process

The refined glass continues on its way through the furnace to the working zone, gradually cooling as it gets farther away from the fire of the furnace. By the time it has reached that zone, it should be sufficiently cooled to permit the necessary handling by the workmen. Unless the furnace is properly constructed, it is impossible to secure the even gradations of temperatures necessary to obtain glass of suitable working consistency. Our furnaces have demonstrated their efficiency in this respect by producing more glass of good quality than any other window glass furnaces of which we have any knowledge.

BLOWING AND DRAWING THE CYLINDERS



Cutting cylinders into short lengths

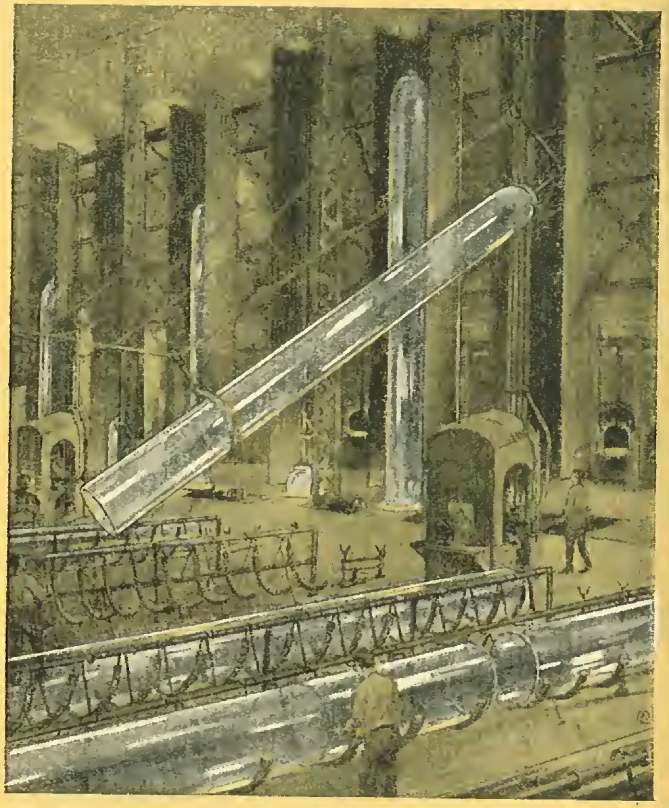
CHAPTER VI

LADLING AND BLOWING

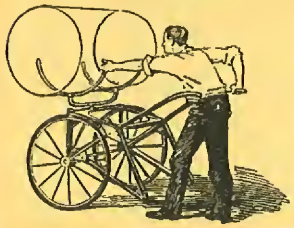
TODAY, window glass is either blown in the old-fashioned way by hand and lung power, a method that is fast dying out, or is drawn in sheet form from a forehearth attached to a tank furnace, or is made by the American Window Glass Company's method of drawing and blowing it mechanically in the form of large cylinders, a process invented by John Lubbers.

In our process, by means of a ladle that holds enough glass to make one large cylinder, or as much as would fill a good-sized bass drum, the molten glass is ladled from the huge melting furnace into a comparatively small pot located in a fixed position beneath the drawing and blowing machine. This pot is reversible; that is, with a working cavity on each side, and is mounted in a small furnace, or heated drawing kiln. Each of our very large tanks has twelve of these drawing kilns, and each of the smaller ones has eight.

As soon as the upper cavity of the pot is filled with molten glass, the operator lowers into the glass a



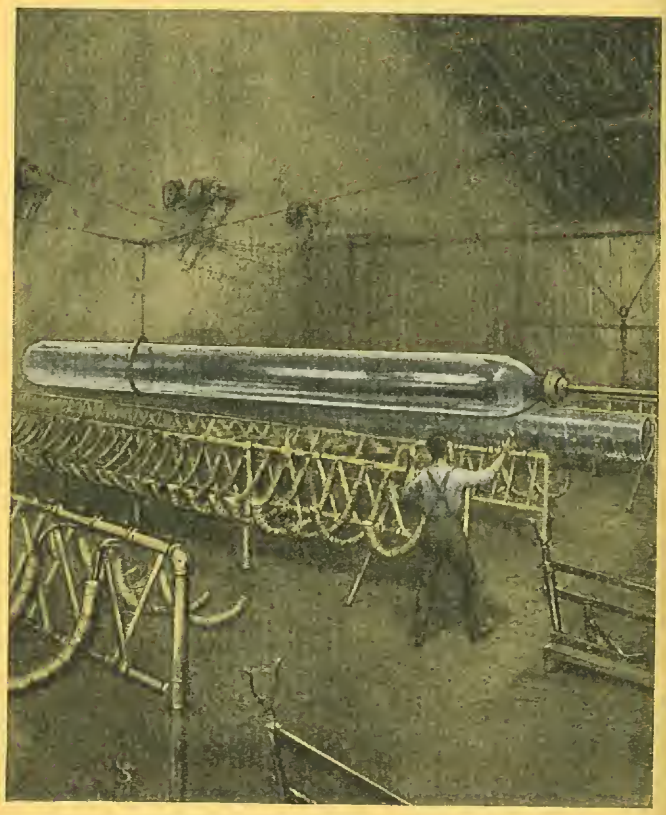
COMPLETED CYLINDER
(Cylinders in foreground being cut into short lengths)



Carrying glass before splitting

hollow stem blow pipe, with a mushroom-shaped head. This blowpipe is hung on a cage that travels vertically between a pair of guides erected above the pot and is connected to a telescoping air supply pipe. A motor driven fan supplies the air pressure. The blowpipe, having taken hold of the glass, is then slowly elevated by the machine, which, at the same time, introduces at the glass level a small quantity of air. As the blowpipe is elevated, the amount of air is gradually increased, and the plastic glass is uniformly and gradually distended in a swelling curve like the neck of a bottle, until it attains the diameter desired for the cylinder. The machine then continues to elevate the blowpipe and automatically furnishes the amount of air needed to keep the cylinder distended to a uniform diameter until it reaches the limit of the length of its draw.

When the cylinder is completed, the lower end is severed from the glass in the pot; and by another mechanical device it is quickly lowered into a horizontal position and placed on a "horse," a receptacle especially designed to receive it. As soon as one cylinder is completed, the pot is reversed, and the other side of the pot is turned up into the drawing position, ready to receive a ladle of glass for the next cylinder. During the drawing of one



LOWERING COMPLETED CYLINDER

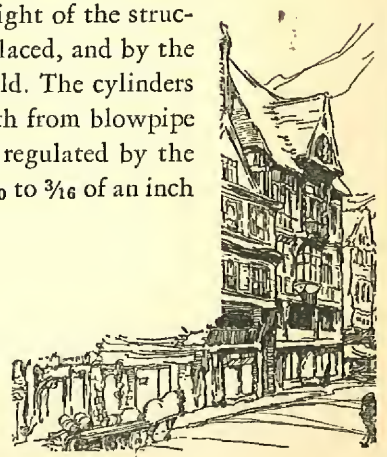
(The drawing and lowering are entirely mechanical)

Splitting cylinders before flattening

cylinder, the fire in the kiln melts out the cold glass remaining in the under side of the pot after the drawing of the preceding cylinder and prepares it to receive the glass for another cylinder. This renders the operation practically continuous.

Like mushrooms, these huge cylinders grow from the molten glass in the pots, rising slowly and silently, impelled as if by an unseen power, to a great height, until their tops almost disappear in the shadows of the building structure. When finished they resemble enormous bottles. Some idea may be gained of their size when you consider that if one of them were filled with milk it would hold 6804 quarts, or about seven tons.

They are made in various lengths, diameters, and thicknesses. The diameters are regulated by the air pressure introduced into the cylinder, and average about 30 inches in commercial operation, although we have made them 48 inches. The diameter of the pots from which they are drawn, of course, limits the diameter of the cylinders that can be made. Their length is limited by the height of the structure on which the machines are placed, and by the amount of glass the pots will hold. The cylinders usually are about 48 feet in length from blowpipe to "hole end." The thickness is regulated by the speed of draw, and varies from 1/30 to 3/16 of an inch in thickness.



Windows along a street in Wales

ADVANTAGE OF OUR BLOWING PROCESS

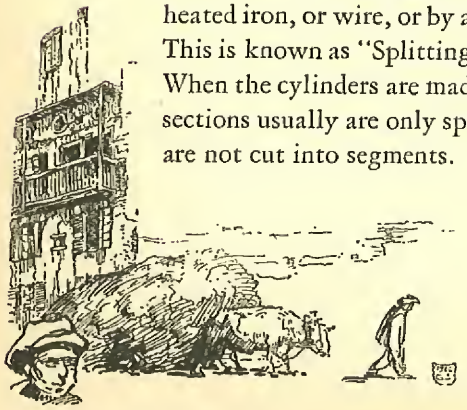
Our mechanical process of drawing and blowing the cylinders imparts to the glass a preliminary annealing, and so affects the physical structure of the glass as to render it stronger and tougher than window glass made by any other process. It insures a uniformity of thickness in the glass, far superior to that produced by the hand blowing method, and equal in every way to that made by any other process.

CAPPING

After the large cylinder has been laid on the horse, the upper part, or cap, and any uneven portion of the "hole-end," are removed, and the remainder of the cylinder is cut up into sections of the desired length by means of electrically heated wires. This process is known as "Capping."

SPLITTING

The sections of the large cylinders are prepared for the next stage of the process (the flattening) by cutting them lengthwise into segments of the required sizes, either by means of an electrically heated iron, or wire, or by a diamond splitting tool. This is known as "Splitting," or "Cracking-open." When the cylinders are made of small diameter, the sections usually are only split once lengthwise, and are not cut into segments.



Llivia in the Pyrenees

CHAPTER VII

FLATTENING

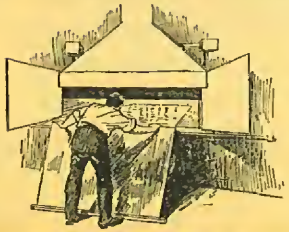
The "cracked-open" sections of the long cylinders of small diameter, and the segments of the cylinders of large diameter are now ready for the next steps in the process—the flattening and the annealing.

For this purpose, furnaces, or ovens, of special design are required. In this country these ovens are all of the same general type, but in Europe quite a different type of flattening oven is used.

Although many improvements have been made from time to time in various other steps of the process of manufacturing, practically none had been made in the flattening process for more than one hundred years, until the American Window Glass Company recently worked out certain changes. These make it possible for this Company to secure better results than can be obtained by any other producer of cylinder drawn glass.

The flattening ovens used in America consist of a horizontal revolving wheel built in four segments and mounted in a furnace, or oven, divided into four compartments. On each segment of this wheel is placed a perfectly flat and highly polished clay

THE FLATTENING PROCESS
(A perfectly flat glass of high lustre is thus produced.)



Annealing accomplished within the lehrs gives the glass strength and greater resistance to breakage

stone, known as a "flattening stone." The oven, of course, is heated to the required temperature, and an inlet canal, or "stick hole," is provided for introducing the glass into the highly heated portion of the oven.

The glass is placed on a small carriage, which is shoved into the heat of the oven adjacent to the flattening wheel. When the glass has been heated to the required temperature, it is then lifted from this carriage and placed on the flattening stone. It is now sufficiently plastic to permit it to be flattened.

If the glass has been introduced into the oven in the form of a segment of the cylinder, the workman at once uses a water-soaked and charred block of wood, called a flattening block, or polisher, with which he rubs or "irons" the surface of the glass and flattens it into a sheet, which conforms to the smooth surface of the flattening stone. When properly done, the block imparts a beautiful lustre or polish to the surface of the glass.

If the glass has been introduced into the oven in the form of sections of cylinders of small diameters that have been split open lengthwise, the workman is obliged to open up the cylinder with a special tool, by spreading it along the lengthwise split or "crack-open" to such an extent that the edges of the split fall away from one another toward the sides of the

flattening stone. He then takes the charred block and irons, or polishes, the glass as before.

Much better results are secured by flattening segments of the cylinder than by flattening the entire cylinder. The development by us of the former method of flattening resulted in a great improvement in the character of the work, in the freedom from defects, and in the appearance of the finished sheet, over that secured by the old-fashioned method.

CHAPTER VIII

ANNEALING

The glass, having just been flattened, is still at a high temperature and must be slowly cooled to permit its being placed in the annealing oven. This cooling effect is accomplished by the subsequent passing of the glass, while still on the flattening stone, through cooler sections of the oven, remote from the fire, until it comes into the section known as the "piling oven." It is now sufficiently cooled to permit the workman to insert a large thin-pronged fork of steel underneath the flattened sheet and to place it on the rods that carry it through the annealing oven, or lehr.

The annealing of the glass consists simply in reducing the temperature of the heated sheet of glass slowly and gradually between two certain temperatures, which constitute the critical range of temperatures for annealing, and then continuing the reduction of the temperature until the glass is sufficiently cooled to permit it to be handled. If the glass is passed too rapidly through this critical range of temperatures, it will not be properly an-

nealed, and it will be hard, brittle, difficult to cut; and it will not withstand ordinary handling or shipping without excessive breakage. In the ordinary oven, these gradations of temperature are secured by advancing the sheet slowly on the rods of the lehr from the piling oven to the discharge end of the oven.

In order to secure the best possible results in the flattening and annealing, the American Window Glass Company has recently made many changes in the old style flattening ovens and lehrs. These changes make possible the production of window glass that is absolutely flat, so far as its use for commercial purposes is concerned. It is as flat as glass made by any of the flat sheet drawn processes.

It is annealed so perfectly, as shown by Government tests, that it equals the annealing necessary in glass made for optical use, which requires the best possible annealing. This results from the double annealing which the glass receives in this process. It is annealed first during the drawing of the cylinder, and again, in its passage through the annealing oven or lehr.

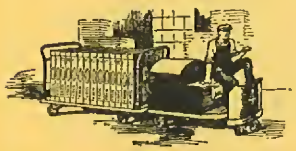
DIPPING AND WASHING

When the sheets of glass are removed from the discharge end of the annealing oven, or lehr, they are dipped and washed in a bath of muriatic acid

diluted with hot water. This is a very important step in the process. The glass, as it emerges from the lehr, has a considerable amount of free alkalies, or other foreign particles on the surfaces, occasioned by the process of manufacture. These foreign particles must be removed; or otherwise, if the glass becomes wet, or sweats, they set up the chemical action that attacks the surface of the glass and causes it to discolor, *i.e.*, fade, stain, or rust. The acid bath thoroughly cleans the surface of the glass of all these foreign particles.

TYPICAL CUTTING STALL

(Expert workmen here cut the glass to required sizes.)



Trucks are used to despatch shipments

CHAPTER IX

CUTTING AND SORTING

When the glass has been thoroughly dried after the muriatic acid bath, it is taken to the cutting room to be cut into the required sizes. The glass is usually cut with a diamond mounted in a cutting tool, but it can be cut just as well with a steel wheel.

When the large sheets of glass are placed on the cutting table, the defects that have been made in all the different steps of the process become apparent. The skilled cutter sees these at a glance and quickly cuts the sheet into the sizes and qualities desired, so far as the quality of the glass will permit. The cutter then "sorts" or "grades" the glass into the different qualities, according to the standards of the company.

The skill and judgment of the cutter in knowing what defects are properly permissible, in any certain quality, are the most important factors in establishing a reputation for high quality glass. All the different processes of manufacturing window glass produce some poor glass, and the reputation of a firm for high quality glass is affected by the

amount of poor quality that is sent back to be remelted, instead of being packed and sent out to the trade.

SORTERS

The various sizes, qualities, and thicknesses of the cut glass are kept separate. All these are carefully examined again by skilled sorters, or inspectors, who rectify any mistakes in grading by the cutters, and who are finally responsible for the finished product conforming to the Company's standard of quality and thickness.

In the grading of the glass, the quality is determined by the defects—the glass of better quality naturally contains fewer and smaller defects than the glass of poorer quality. The rules for grading the glass will be found in the Appendix under the proper heading.

After the glass has passed this inspection it is sent to be packed.

CHAPTER X

BOXES AND PACKING

As a rule, in this country, all window glass is packed in boxes containing the nearest number of lights or panes that will equal 50 square feet, except large sizes containing more than 100 united inches, which are packed in boxes containing as nearly as possible 100 square feet. Some of our specialties are packed in boxes containing 300 square feet.

All our boxes have reinforcing cleats at the tops and bottoms of the heads. They are made according to a definite, uniform rule for the various sizes and thicknesses. The Company's name, the number of the factory, and the size of the glass to be packed in the box are all neatly branded by a branding machine on one of the heads of the box.

For packing the glass in the boxes, we use long, specially threshed, rye straw, which must be kept absolutely free from all moisture, or else the dampness in it will attack the surface of the glass and cause the glass to fade or discolor.

The glass, when finally packed, is thoroughly cushioned by the straw from contact with any part of the box.

All glass is packed in long rye straws to insure safe transportation.

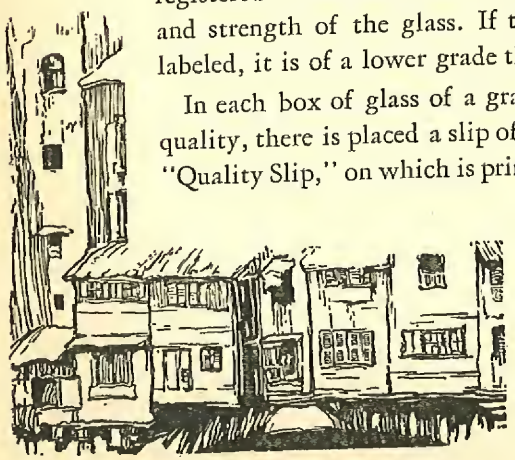
CHAPTER XI

LABELS, QUALITY SLIPS, AND BRANDING

MANY dealers furnish a large amount of single thick glass to consumers as double thick; and a great deal of glass of a low grade of quality as being of a higher grade, because of the increased profit that can be made by these substitutions. This would not be possible if buyers had more knowledge of window glass and its process of manufacture. When dealers resort to that practice, they must change accordingly the branding placed on the boxes by the manufacturers.

On each light of "A" and "AA" quality glass produced by the American Window Glass Company, is placed a label bearing a copy of the Company's registered trade mark and certifying the quality and strength of the glass. If the glass is not so labeled, it is of a lower grade than "A" quality.

In each box of glass of a grade inferior to "A" quality, there is placed a slip of paper, known as a "Quality Slip," on which is printed the Company's



Windows on a Florentine Bridge

name and a certificate of the quality and thickness of the glass contained in the box.

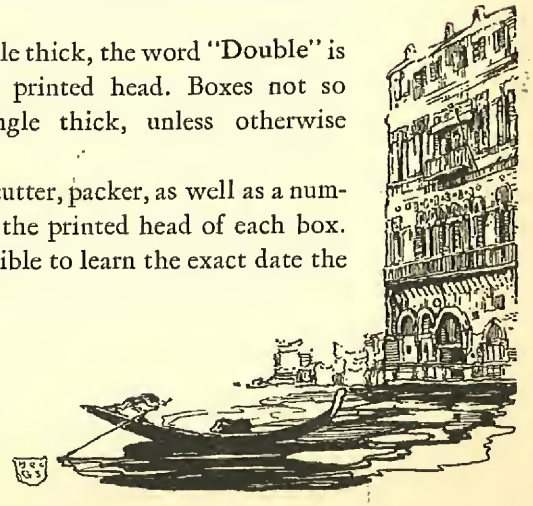
These labels and quality slips are a protection against the substitution of a lower quality for a higher quality of glass or of single strength for double strength. They are an insurance or guarantee to the buyer of the thickness and quality of the glass as packed by us. When a quality slip is not found in a box of glass of the American Window Glass Company's manufacture, an explanation should be obtained to account for its absence.

On the printed head of each box of glass of regular quality, the packer stamps with a steel die, the letters designating the different grades of quality. "AA" indicates the best quality; "A" the next best; and "B" the next lower grade.

On boxes of "off-quality" glass, is stamped the word "Fourth," or the letter "C." The latter indicates the poorest grade of glass packed. The Company's name never appears on boxes containing "C" quality.

If the glass is double thick, the word "Double" is stamped across the printed head. Boxes not so marked contain single thick, unless otherwise marked.

The names of the cutter, packer, as well as a number are stenciled on the printed head of each box. From these it is possible to learn the exact date the



Venetian Palace

glass was packed, and to trace it back through all the different departments that handled it, to the machine on which it was made. In case of any complaint or question regarding the glass, it is essential that the Company be informed of the marks on the box.

CHAPTER XII

WAREHOUSING AND SHIPPING

After the glass is packed, it is taken to the warehouse to be stored or is sent out on shipping orders. Manufacturers and dealers who store their glass in damp or badly ventilated warehouses are certain to have much trouble with the glass fading, even though the composition be of the very best. Everyone who has occasion to store glass for any length of time should inquire carefully into its analysis and ascertain whether it has been dipped in the muriatic bath, so as to make sure that it can be stored safely. In case it is not of the proper composition or has not been properly treated, it is certain to discolor or fade in a very short time when exposed to moisture.

When shipping the glass, the greatest care is taken in loading the cars. The boxes must be securely wedged and braced to avoid shifting in transport. Much unnecessary breakage is caused through ignorance or carelessness of shippers in the proper loading of glass. When a car is properly loaded, the glass will carry with practically no breakage in transit, and is almost invariably received by the customer in perfect condition.

CHAPTER XIII

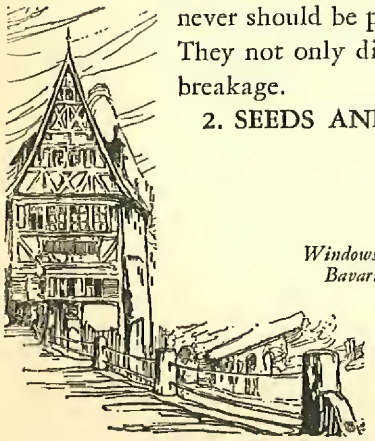
DEFECTS IN GLASS

MELTING DEFECTS

If the materials used in making the glass have not been of sufficient purity and fineness, or are not well mixed in correct proportions, or if the furnace has not been operated in a proper manner, the glass will contain many defects that could have been avoided. Of the defects that may be found in any kind of glass, the following are the most important ones, occurring in the melting and refining stages of the process:

1. STONES—These may be of silica or clay, resulting either from particles in the composition too large to be melted, or coming from the furnace structure itself. They may also be caused by wrong proportions of the ingredients, by devitrification, or by the improper operation of the furnace. No matter what the cause or the nature of them, they never should be permitted in the finished product. They not only disfigure the glass but cause great breakage.

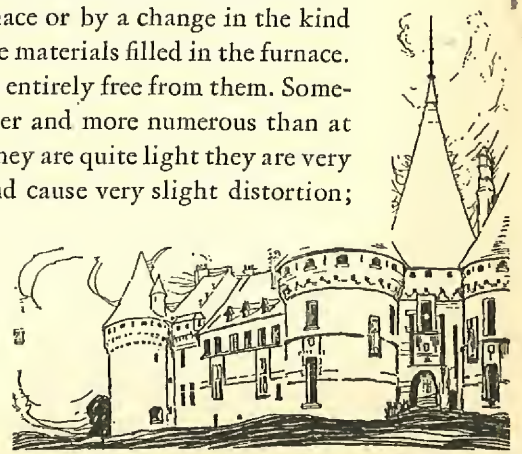
2. SEEDS AND BLISTERS—Frequently, after



Windows in a Bavarian Town

the glass has reached the working zone, we find bubbles of various sizes, formed by the gases given off by the chemical action that takes place in melting, or by atmospheric air enclosed in the composition, which, from various causes, have not been able to escape. Similar bubbles are also formed in working through the carelessness or incompetence of the workmen in permitting small portions of air to be enveloped in the glass. In the subsequent stage of the process these bubbles are elongated to a greater or lesser extent, taking on an elliptical shape according to their size and the process of manufacture. The very small ones are called "seeds," while the larger ones are called "blisters."

3. WAVES OR REAM—These are wave-like streaks or bands visible in the finished glass when viewed at a sufficiently sharp angle or in a reflected light. They appear to be of a slightly darker greenish tint, and are slightly thicker than the other portions of the glass. They indicate a lack of homogeneity in the glass, caused either by irregularity in the heat of the furnace or by a change in the kind or proportions of the materials filled in the furnace. Scarcely any glass is entirely free from them. Sometimes they are heavier and more numerous than at other times. When they are quite light they are very difficult to detect and cause very slight distortion;



Windows in a French Chateau

but when they are heavy, the distortion is considerable. This defect is properly called, "ream."

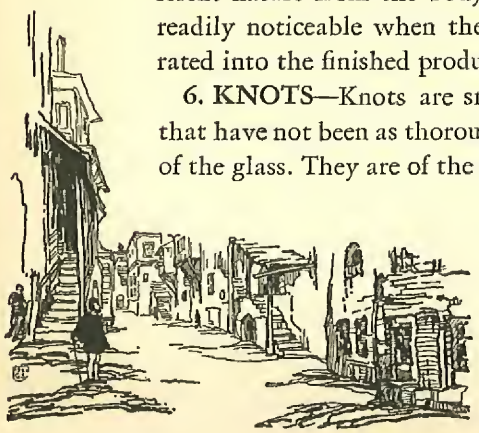
4. **CORDS AND LINES**—"Cords" is the name given to threadlike streaks often found in glass, that appear to be of a different nature from the main portion of it. They hinder the vision through the glass. Sometimes they cover the entire piece, and at other times only a portion of it.

They are caused either by a too sudden lowering of the heat of the furnace or by the chilling of the glass that is being "worked up" into the finished product.

In the hand-blowing process of manufacture they usually extend around the cylinder in more or less irregular fashion. In the mechanical process, they extend in parallel lines in the direction in which the glass is drawn and are sometimes known as "lines."

5. **STRINGS**—These are fine transparent threads of glass that are not made in the ordinary melting but which come from the vitrifying of some portion of the furnace structure. They are of an entirely different nature from the body of the glass and are readily noticeable when they have been incorporated into the finished product.

6. **KNOTS**—Knots are small particles of glass that have not been as thoroughly melted as the rest of the glass. They are of the same color as the glass



Windows—
Mt. Athos, Greece

but noticeably of a different nature. Sometimes they are entirely clear, like very small glass beads; at other times they may have a grain of sand imbedded in them. It is a defect quite similar in character to stones, except that the stones are not vitrified like the knots. They should never be allowed in the finished product because they disfigure the appearance of the glass and cause excessive breakage.

FLATTENING DEFECTS

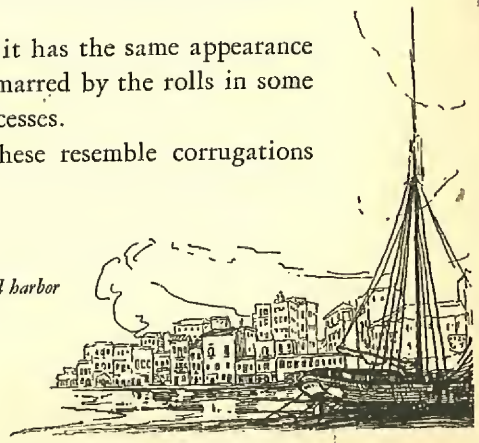
Formerly many defects were introduced into the glass in this step of the process, though our recent inventions demonstrate that none of them are inherent or necessary; all result from either carelessness or lack of skill by the workmen, or failure to control the process scientifically.

The following are the principal defects found in some of the flattened glass:

1. **BURN**—This results from running the oven at too high a temperature or permitting the glass to remain too long on the flattening stone. This causes the glass to have a faintly pimpled or slightly sanded appearance.

When glass is burnt it has the same appearance as glass that has been marred by the rolls in some of the sheet drawn processes.

2. **WRINKLES**—These resemble corrugations



Canea—an old harbor
of Crete

in the glass caused by the sheet not having been entirely "ironed out" on the flattening stone.

Glass containing wrinkles never should be packed, because they always cause breakage.

3. COCKLES—These are slightly raised places on the surface of a sheet of glass, caused by the failure of the flattener to "rub out" properly the flattened sheet.

When these are found in cylinder made glass, this defect is identical in appearance with the humps and depressions found in glass made by some of the sheet drawn processes.

OTHER DEFECTS

SCRATCHES—The most common defect in all glass is scratches. They are found in every kind of glass that is made, regardless of the process of manufacture. From the time the glass passes from the plastic state to the solid, it is liable to be scratched at every stage of the process and with every handling. They are usually caused by the lack of care or skill on the part of the workmen, but sometimes by the process of manufacture.

They are on the surface of the glass. Some are very large and heavy, while others are very fine, light, and almost imperceptible except to the trained eye. Few realize how easily glass can be scratched

by drawing a hard, rough substance across its surface, or how the scratches disfigure it. More good glass is spoiled by scratches than by any other defect.

FADED GLASS (Stain or Rust)—All window glass, regardless of its composition, is susceptible to attack by chemical action that begins with moisture, and will therefore discolor or fade, no matter whether or not it has been previously dipped or washed in the dilute muriatic acid bath, unless the acid bath is sufficiently strong to cause the surface of the glass, when dried, to show an acid reaction. Glass not so treated will discolor or fade very much more quickly than the glass that has been so treated. If the acid bath is too strong, it produces a "hum," or cloudy appearance on the surface of the glass, which renders it very difficult to detect the defects. Sometimes manufacturers use an excessive amount of the acid to hide the poor quality of their glass.

When moisture occurs on the surface of the glass, either from sweating or from any other cause, and it comes in contact with ordinary dirt or carbon, it sets up a chemical action that attacks the surface of the glass and causes the discoloration that we call "fade." This is sometimes called "stain" and sometimes called "rust." It manifests itself at first

by an iridescence on the surface of the glass, as though carbon oil had been placed on it, which dulls its lustre. If the chemical action continues a sufficient time, the glass then takes on a frosted appearance, which will gradually increase, until the glass finally becomes opaque. Glass containing too much soda or too little lime will fade very quickly.

Careful housewives have spent many hours of wasted efforts trying to wash or rub off the oil-like stain, caused by "fade," on the glass in the windows of their homes. In the early stages of fade, the discoloration can be removed only by dipping the glass in an acid bath; but if the glass has become quite opaque, nothing can be done to restore its former brilliant surface.

CHAPTER XIV

WINDOW GLASS WAVE

After cylinder blown window glass is flattened, its surface shows a slightly wavy or rippled appearance that can only be detected when viewing the glass at a sharp angle between the line of sight and the glass. It results from the fact that the outside surface of the cylinder is longer than the inside; and when flattened, it must be compressed, as it were, within the same space as the inside surface. It is not a defect.

All window glass, no matter by what process it is made, presents an appearance practically identical with that caused by the window glass wave, when it is viewed at the same angle. In some of the sheet drawn processes it is much more pronounced, and causes greater distortion.

Prior to the invention of the sheet drawn processes, it was believed that glass drawn in sheet form would have an entirely different appearance from cylinder made glass. Unfortunately, the expectations of the inventors were never realized. All such glass still retains the characteristic appearance of cylinder made window glass. In the sheet drawn processes this results from slight temperature varia-

tions in the bath of glass or lack of homogeneity. When the plastic glass is subjected to the drawing and stretching strains, these differences in the glass temperatures produce a more or less wavy appearance in the drawn sheet, similar to that of the window glass wave in cylinder made glass.

CHAPTER XV

OUR PRODUCTIONS

THE following are our productions in clear window glass, listed in the order of their thicknesses or weights, beginning with the thinnest:

Microscopic Slides
Lantern Slide Glass
Photo Dry Plate Glass
Diagnostic X-Ray Glass
16-oz. Picture Glass
Single Strength Glass
Double Strength Glass
26-oz. Glass
29-oz. Glass
34-oz. (4½ *millimeter*) Crystal Sheet
39-oz. (3/16″, *or* 5 *millimeter*) Crystal Sheet

We also produce the following "Processed Glass":

Ground Glass
Chipped Glass, 1 Process
Chipped Glass, 2 Processes

When glass is described as of a certain weight, it means the weight per square foot of that thickness.

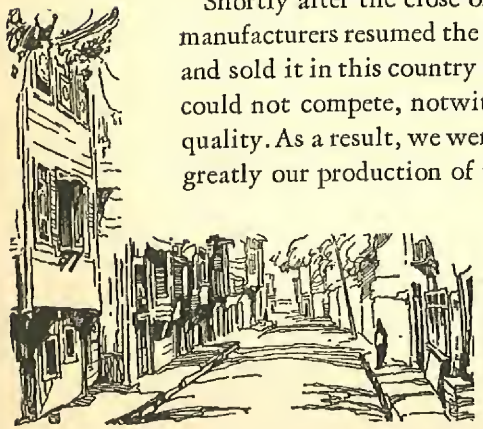
A square foot of window glass one inch thick weighs, on the average, thirteen pounds.

All of the foregoing productions are of the same composition and are made by the same process. They differ from one another only in the thickness, flatness, and selection of quality, according to the special purpose for which the glass is to be used.

MICROSCOPIC SLIDES, LANTERN SLIDE GLASS, PHOTO DRY PLATE GLASS, AND DIAGNOSTIC X-RAY GLASS

The above named productions are all of the same general class. They are much thinner than other glass, and they require absolute flatness and the very best quality. We are the only manufacturer in this country who can produce such glass. Years ago attempts were made to produce it here by the hand blowing method, but without success. In 1913, after some years of experimenting and an enormous expenditure of money, we began its production on a commercial scale, and succeeded in producing a quality superior to that of imported glass.

Shortly after the close of the war, the European manufacturers resumed the production of this glass and sold it in this country at prices with which we could not compete, notwithstanding our superior quality. As a result, we were obliged to curtail very greatly our production of this kind of glass.



Windows on a by-street of Constantinople

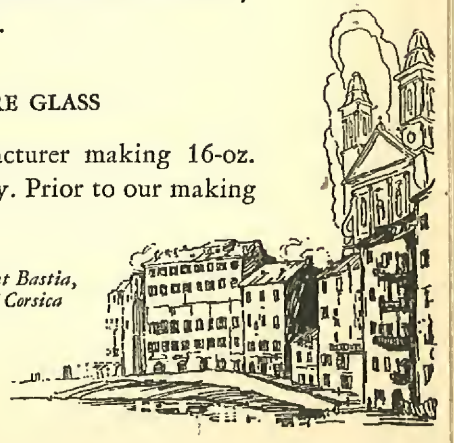
When our country went into the war, we were the only manufacturer here that could make the kind of glass required for eye pieces for gas masks. These were made of very thin glass, cut into circles about 2½ inches in diameter. They were subsequently placed together in pairs with a thin coating of liquid celluloid between them and were then subjected to very great pressure. If the glass was not perfectly flat, or was not cut with a perfectly smooth edge, the celluloid would not bind the two circles together sufficiently to permit them to be used.

This process had the effect of rendering the glass "non-scatterable"; that is, pieces would not break off and fly, when it was struck a very heavy blow. Under the concussion the glass would crack, but all the particles would remain firmly held together by the celluloid binder.

Through the patriotic assistance of men, women, and children of a Red Cross Unit during the war, in volunteering to learn to cut this glass when other labor was not to be had, we were able to furnish 27,000,000 of these circles for the use of our army and the armies of our Allies.

16-OZ. PICTURE GLASS

We are the only manufacturer making 16-oz. Picture Glass in this country. Prior to our making



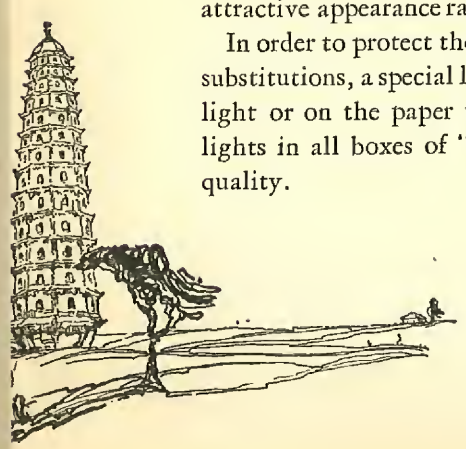
Windows at Bastia, a port of Corsica

it, all such glass was imported from Europe, but our glass proved to be of such superior quality that very little is now imported. It is thinner than single strength window glass, ranging in thickness from 12½ to 14 lights to the inch, but is graded to a much higher standard of quality. It is sold in three grades, under the trade designations of "Superfine," which is the best quality; "Selected," which is a very fine quality but not quite equal to the best; and "Commercial," which is a somewhat poorer grade but superior to "B" quality window glass.

In producing it great care must be taken at every stage of the process, and only the most skilled men handle it. As a result, it has the even thickness, flatness, smoothness of surface, lustre, and freedom from defects so necessary in glass used in framing high grade pictures.

It is purposely made thinner than ordinary window glass in order to transmit more light than the thicker glass. Its exceptional quality makes it also especially adaptable for use in mirrors, French doors, and for any other purposes that require glass of very attractive appearance rather than of great strength.

In order to protect the buyer of this glass against substitutions, a special label is placed either on each light or on the paper that is placed between the lights in all boxes of "Superfine" and "Selected" quality.

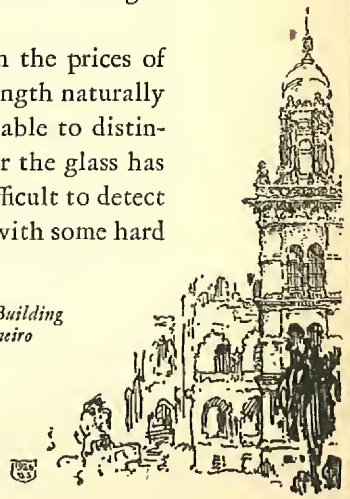


Pagoda of the Sung Dynasty

SINGLE AND DOUBLE STRENGTH WINDOW GLASS

More than 90% of all the window glass used annually in this country is in these two thicknesses. The single strength, as its name would imply, is much thinner and consequently lighter in weight than the double. That is really the only difference so far as the glass itself is concerned. Greater care is always taken with the double strength glass and the most skilled men are used in making it, on account of the increased difficulty in handling it. While the rules for grading are the same for both thicknesses, yet the double strength is apt to appear slightly better than single strength. The greatest possible care is used with both of these thicknesses, and there should be no material difference in the grading. The thinner glass should be used in places where the strength or thickness is not an important factor; but where the windows are exposed to very heavy winds, it is safer to use the double strength glass.

There is considerable difference in the prices of the two thicknesses—the single strength naturally costing less. The buyers should be able to distinguish between the thicknesses. After the glass has been glazed in the sash, it is very difficult to detect the difference. By tapping the glass with some hard



A Government Building in Rio de Janeiro

substance the thinner glass resounds more faintly than the double thick.

Complete details as to the thickness, flatness, and the rules for grading the above named productions will be found in the Appendix under the proper headings.

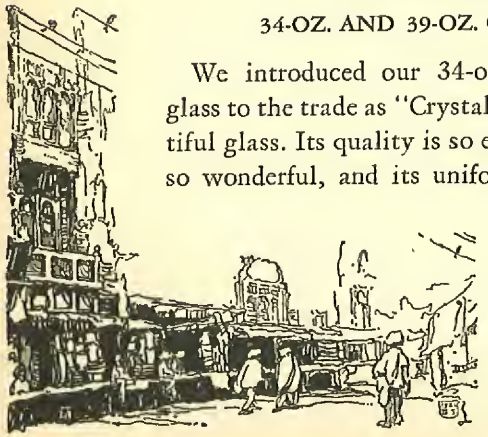
Those who use our glass for whatever purposes window glass is required, can be assured of having "The Best Glass" made. In the evenness of its thickness, in the flatness of its surface, in the brilliance of its polish, in its durability and physical strength—it is not equalled by window glass made by any other process.

26-OZ. AND 29-OZ. GLASS

These two kinds of glass differ from the regular double thick glass in their thickness, special flatness, and higher standard of quality. Those requiring glass slightly heavier than double thick, and of a specially fine quality, will find that this glass will meet their every requirement.

CRYSTAL SHEET
34-OZ. AND 39-OZ. OR 3/16" GLASS

We introduced our 34-oz. and 39-oz. or 3/16" glass to the trade as "Crystal Sheet," a really beautiful glass. Its quality is so exceptional, its flatness so wonderful, and its uniformity of thickness so



India—the Balconies of Lahore

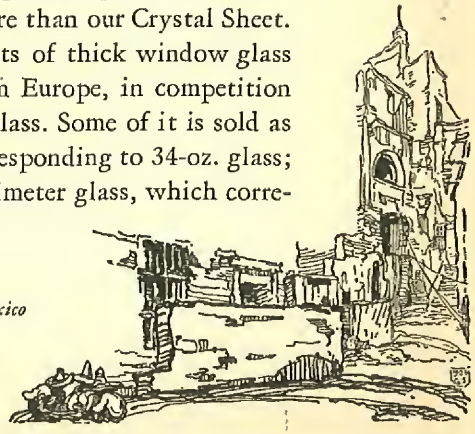
perfect that it is adaptable for many purposes for which plate glass has ordinarily been used. In the smaller sizes it presents such a fine appearance that only an expert can distinguish it from plate glass.

It is suitable for glazing office buildings, hotels, hospitals, public buildings of all kinds, and dwellings, in which not only the appearance of the glass is very important, but the thickness and strength as well. Large quantities of it are used in automobiles, for windshields, bodies, and accessories. It is also used for typewriter keys, clock faces, showcases, counters, shelving, car windows, small mirrors, desk and table tops, and other furniture.

All this glass is handled with special care. It is packed with paper between the lights, and every light is labeled to identify the quality and thickness for which it is sold.

Being thinner and consequently lighter in weight than plate glass it does not require window sash of special construction, nor the use of extra heavy sash weights, which are necessary when using plate glass. It is also much cheaper than plate glass which costs about one-third more than our Crystal Sheet.

Recently, large amounts of thick window glass have been imported from Europe, in competition with our Crystal Sheet glass. Some of it is sold as 4½ millimeter glass, corresponding to 34-oz. glass; and some is sold as 5 millimeter glass, which corre-



Windows in Guanajuato, Mexico

sponds to 39-oz. or 3/16" glass. This foreign glass is made by a sheet drawn process that requires a different composition from that used by the makers of good window glass. Analyses show it to be high in soda, low in lime, and low in silica, and it therefore lacks the strength, density, and resistance to fade or stain of our glass, and it will not warehouse as well.

PROCESSED GLASS

This is either in the form of ground glass or chipped glass. Ground glass is made by sandblasting one surface of clear window glass, which gives it a slightly frosted appearance that renders it suitable for obscuring purposes.

This glass is often subsequently coated on the ground side with glue, and placed in heated drying kilns. In drying, the glue "cracks off," taking with it thin particles of the surface of the glass, producing a chipped effect. When the glass has been subjected to this process only once, it is known as "chipped one process," but when the process is repeated, it is known as "chipped two processes."

The chipping gives the glass a very attractive and unique appearance. The surface appears to have leaves of all sizes, kinds and shapes, cut into the glass with all the beautiful veinings seen in forest leaves. The chipping, of course, hinders the transmission of light. Very beautiful effects can be produced with this glass, either by itself or in combination with ground glass. It is very suitable and most attractive when used in door lights, transoms, cabinets, screens, partitions, and windows.

CHAPTER XVI

COMPARISON OF GLASS

WHILE we have gone exhaustively into the matter of the defects to which our glass is subject, we wish to call the reader's attention to the fact that all glazing glass, whether it be rolled glass, plate glass, or window glass, and irrespective of its process of manufacture, is subject to most of the same defects. Those described under the heading, "Melting Defects," are common to all kinds of glass, without any exception. In addition, each kind is subject to certain other defects that are incidental or characteristic of the process of manufacture.

OTHER WINDOW GLASS

Comparing window glass made by different processes, one will find the same kind of defects in each, though they may result from different causes. One process will accentuate certain kinds of defects, while other processes accentuate others. The process is never an argument as to the quality of the product. That, as we have seen, depends largely upon the methods of manufacturing.

Some processes of manufacturing window glass

have certain advantages over others. For the most part these are confined to an economy of labor, fuel, or both. Our process not only effects these economies, but with our manufacturing methods it enables us to produce a larger percentage of glass of the higher grades of quality than any other process in use throughout the world today.

On account of the composition we use, our methods of drawing and blowing, and the double annealing which the glass receives, our glass is less brittle and has a better nature than any other window glass.

In the Appendix we have inserted tables showing the tensile strength and modulus of rupture of our glass. A comparison of these tests with similar tests of any other window glass, plate glass, or rolled glass, proves that our glass is stronger per unit of thickness than any other glass.

In conclusion, the superiority of the American Window Glass Company's glass over any other window glass may be summed up in the following closing sentences:

It is the most durable glass.
It is the strongest glass.
It is "The Best Glass."

APPENDIX

U.S. Government Master Specifications
with our comment

(U.S. Government Specifications are printed in Italics)

APPENDIX

OWING TO THE FACT that single strength window glass costs much less than the double strength glass, and glass of a lower grade of quality costs much less than glass of a higher grade, some dealers taking advantage of the fact that few buyers of window glass are familiar with the rules for grading glass, resort to the practice of substituting the thinner glass for the thicker glass, and the lower grades of quality for the higher grades. This practice has greatly increased during the past few years on account of the severe competition in the business, and innocent purchasers suffer as a result of it.

Buyers heretofore have been unable to protect themselves against these substitutions, by reason of not having any positive and authoritative information regarding the thicknesses of window glass and the rules for grading it. This information is now furnished by the United States Master Specification, prepared by the Bureau of Standards, after very exhaustive study and research. It is known as Specification No. 123, a true copy of which is set forth in this Appendix.

This Specification was officially adopted by the Federal Specifications Board on April 1, 1924, for the use of the Departments and Independent Establishments of the Government in the purchase of flat glass for glazing purposes. It is a valuable guide for manufacturers, architects, jobbers, dealers, glaziers, users, and buyers generally, regarding the sizes, thicknesses, qualities, and rules for grading window glass. A careful study of it will qualify one to judge window glass, and to know whether the glass furnished is of the thickness and quality for which it was bought.

Since this "Master Specification" was published, a number of changes have taken place in the character of the window glass produced in this country, and in the designation of some of the qualities. Attention is called to these changes under the appropriate headings. We have also added such explanatory notes and comments on the "Master Specifications" as will give the reader a clearer understanding of the subject.

Those who wish to buy window glass of the highest quality, that conforms in every way to the "Government Specification," should specify the American Window Glass Company's brand—"The Best Glass." It is the best glass for the fourteen reasons we have outlined at the end of this pamphlet.

Architects who desire "The Best Glass" for the buildings they design should specify it as follows:

> **"All window glass to be used in this building shall be the American Window Glass Company's make or equal thereto, and shall be (*here specify the thickness and quality of glass desired*). All "A" quality glass furnished must have the manufacturer's label on each light."**

If the American Window Glass Company's glass is specified, the company will follow up the job whenever requested, without any expense to the party requesting it, and report whether the glass furnished is the kind, quality, and thickness specified.

"Definition of Clear Window Glass"

"Clear Window Glass"—*Transparent, relatively thin flat glass having glossy, fire finished, apparently plane and smooth surfaces, but having a characteristic waviness of surface which is visible when viewed at an acute angle or in reflected light.*

"Clear Window Glass" *is made at present by hand blowing, or by machine blowing and drawing into cylinders and flattening, or by drawing directly into a sheet, the surface finish being that obtained during the drawing process.*"

The "characteristic waviness" referred to in the foregoing definition should be distinguished from the heavy waves frequently noticed in glass of poor quality. These have the appearance of wide bands

or streaks extending across the sheet, of a slightly darker tint than the main body of the glass. It is a defect called "ream" and causes considerable distortion.

"General Principles Involved in Grading Glass"

"All flat glass contains some imperfections and the principle employed in grading is to exclude all defects that would be objectionable in a given grade. This is difficult to do since there are no sharp lines of demarcation between grades, and experienced inspectors will differ in judgment as the quality of the glass approaches the limits of the grades. Small lights must be quite free from imperfections as compared with larger ones, and the center of any sheet should be clear whereas the edges may contain more pronounced defects."

"Central Area of the Sheet"

"In window glass the central area of the sheet is considered as being a circle having a diameter equal to half the width of the sheet or an ellipse having one diameter equal to half the length of the sheet and the other diameter equal to half the width of the sheet."

Terms

"The following terms shall be used in specifications as applying to clear window glass: seeds, blisters, lines, burns, scratches, strings, cords, stones."

To these should be added "ream" and "cockles."

Definitions, causes, and brief descriptions of these various imperfections are all set forth in the chapter "Defects in Glass."

Defects Prohibited in All Grades

Stones, knots, very heavy lines or cords, long or raised blisters, wrinkles, heavy burn, foreign particles adhering to the surface of the glass, deep scratches, fade or stain, and in general every defect that might cause excessive breakage is prohibited in all grades of window glass.

"Method of Examination"

"The method of examination is described in these specifications in order to make the results more uniform and defines the condition under which glass should be examined because the distance from the glass, the angle between the glass and the line of sight, and the intensity of light all affect the visibility of imperfections.

"These specifications should be interpreted by examining the glass in the following manner, with reference to the definitions of defects listed in the glossary (U. S. Specifications):

"The glass should be examined when placed in a position similar to that of a glazed light with the observer's eye on a level with the center of the sheet, and looking through the glass from a distance of about 36 inches into the light from a clear sky without any sun or any close background.

"The visibility of waves, lines or cords depends chiefly upon the angle of observation, and the intensity of these

defects can be classified on this basis. The values given for angles are the angles the line of sight makes with the sheet of glass when in a vertical position. Slight movement of the head horizontally through an angle of two or three degrees will make waves or lines more perceptible."

"Acceptance or Rejection"

"*Acceptance or rejection of a shipment or delivery shall be based on an examination of the following quantities:*

"*For orders of* 100 *lights or less, all shall be examined; for orders of* 101 *to* 500 *lights at least* 50% *shall be examined; for orders of* 501 *or more lights at least* 25% *shall be examined. Boxes shall be selected from the shipment at random.*

"*If not more than* 10 *per cent of the lights examined are below quality, the shipment shall be accepted provided the lights below the specified grade are not distinctly below the upper limit of the next lower grade.*

"*If, however, an entire shipment of* 500 *lights or more is examined, not more than* 5% *may be below quality.*"

The foregoing specification was drawn to cover the delivery of glass "to the job" in small lots. In carload shipments it is customary to judge the glass by the quality found in 25 or 50 boxes of the shipment, selected at random.

"Specifications for Clear Window Glass for Glazing"

"*Clear window glass for glazing is made in several different qualities and in the varying thicknesses shown in Table* 1, *page* 95.

"*Single strength and double strength window glass is regularly supplied in two standard qualities, known as A quality and B quality. A limited amount of this glass, known as AA quality, which is especially free from defects, is sometimes selected for special purposes and may be specified if desired. It must be borne in mind, however, that the total amount of AA glass produced by the manufacturers does not exceed* 3% *of the total amount of window glass produced.*

"*There is also a limited amount of single strength and double strength glass produced in a quality inferior to B quality, and is known as Fourth quality. The amount of glass produced in this quality also represents a very small percentage of the total window glass produced.*

"*A quality of single strength glass inferior to Fourth Quality is also produced in very limited quantities, and is known as C quality. This is the lowest grade of glass that is packed and marketed in this country.*

"*Window glass is also produced in thicknesses heavier than double strength, and according to its thickness it is classified as* (1) 26-*oz. glass;* (2) 29-*oz. glass;* (3) 34-*oz. glass;* (4) 39-*oz. or* 3/16" *glass.*

"26-*oz. and* 29-*oz. glass are produced only in A and B qualities.*

"34-*oz. and* 39-*oz. or* 3/16" *glass are produced in glazing and factory run quality.*"

RULES FOR GRADING

"AA" Quality

This quality requires the best grade of glass obtainable, but it does not require perfect glass or substantially perfect glass. As a matter of fact, it is impossible to produce flawless glass of any kind, in large sizes or quantities. The finest glass made only approximates flawless glass; and the larger the dimensions, the more flaws it will contain.

Defects of various kinds are permissible in this quality, but they should be very slight or not discoverable except on close inspection.

In general, the center of each light must be practically free from defects. Each light must be viewed as a whole, and not judged by single defects in different parts of the light.

On account of our very high standard of grading, it is impossible for us to produce this quality in sufficient quantities to enable us to fill orders for it quickly. Buyers who insist upon having it must expect greater delay in the shipment of their orders than when ordering the other qualities.

The price of this quality is considerably higher than that of "A" quality. This is made necessary by the large amount of waste occasioned in manufacturing this quality and by the additional labor cost involved in producing it.

"A" Quality

"The defects permitted in this quality are faint strings or lines, slight burn, small seeds, small blisters, and light scratches.

"No light shall contain all of these defects, and those present may not be grouped when in the central area of the sheet.

"Strings, lines, or burn specks shall not be of such intensity that they are visible when observing the sheet at an angle greater than 30 *degrees between the line of sight and the glass.*

"Waves shall not be visible at an angle greater than 20 *degrees with the glass.*

"Blisters shall not exceed ¼ inch in length unless they occur near the edge of the sheet.

"In general, the central area of the light shall be practically free from defects, and the appearance of the light as a whole shall be such that there is no perceptible interference with the vision as long as one is not looking through the glass at an acute angle."

It is exceedingly difficult to judge defects by viewing the glass at a specified angle, for the reason that the slightest motion of the head or the eye will change that angle. Moreover, the eye takes in such a large portion of the surface, that one part of the sheet will be viewed at one angle and another part will be seen at a very different angle.

The limit of the angle at which waves are visible is too low. There is no good reason why waves or ream may not be visible at as large an angle as strings and lines without unduly affecting the quality.

"A" quality should be used in windows of all buildings the appearance of which is an important factor. Today, a very large percentage of the glass used even in the finest buildings is either "B" quality or even a lower grade, because it is cheaper, although doubtless a very large percentage of it is specified in "A" quality. A building glazed with the poorer grades of glass does not present the appearance of one glazed with "A" quality.

No specific rule can be laid down as to the size of any defect permitted. A defect too large for a small light might be permitted in a much larger light. The location of the defects also determines the number and size permitted. Seeds and small blisters that would not be permissible in the center of the light would be allowable if remote from the center.

To protect the architects and buyers who desire to use the best quality of window glass, we adopted the practice of putting a label on each light of "A" and "AA" quality. For their further protection the architects and buyers should be able to distinguish the inferior grades of glass when they see them.

"B" Quality

"This quality admits of the same kind of defects as A quality, but they may be larger, heavier and more numerous.

"Occasional scattered blisters not more than ½ inch long may occur over the central area of the sheet. Larger blisters up to 1 inch in length may occur about the bordering areas.

"Waves should not be of such intensity that they are visible when observing the sheet at an angle greater than 45 degrees with the glass, unless on the border.

"Burn spots may be visible when looking directly through the glass, but they must not cause any appreciable depression and the speckled appearance must not be so great as to interfere with vision when examining the glass in the specified position."

In general, the defects permitted in this glass are so prominent as to attract the attention of the casual inspector at once; but they should not be so numerous as to prevent a considerable portion of each light from being reasonably free from them.

In buildings where the cost of construction is the most important factor, "B" quality glass should be used. However, great care should be taken to obtain the highest standard of "B" quality. There are many factories turning out glass branded "B" quality

which is really only "Fourth," and even "C" quality. Such brands are always sold at lower prices than our "B" quality, but the difference in prices does not compensate for the great deficiency in quality of the cheaper glass. Buyers should insist upon having the American Window Glass Company's quality slip in each box of "B" quality.

"Fourth" Quality

Since the Master Specification was published, the amount of single strength and double strength glass produced in this quality has increased very greatly.

Glass of this grade is known to the trade as "off-quality" glass, and is not subject to rejection on account of defects. No very definite rules can be laid down for the grading of this quality. Glass that is too poor for "B" quality is usually classed as "Fourth" quality, unless the defects are so many and so glaring that they leave practically no portion of the light free from them, in which case it is classed as "C" quality. It may contain many prominent defects that will hinder the view or distort the appearance of objects viewed through it. These include blisters, heavy lines or cords, ream, cockles, and heavy burn.

On account of the disfiguring and distorting defects found in glass of this quality, it should never be permitted to be used in dwellings, schools, or other buildings where the appearance of the building or the vision of the occupants is a factor. It sells at very much lower prices than "B" quality, and much of it is substituted for "B" quality in window sashes that are sold in markets where "price is the only consideration."

"C" Quality

This is another type of "off-quality" glass, of a lower grade than "Fourth" quality. It is really rubbish that should be remelted instead of being sent out to the trade. Such glass is usually not fit for use for any purpose except hotbed sash, and it is generally produced only in single strength, in a limited number of small sizes, none of them larger than 12 x 18.

It is sold at very much lower prices than "Fourth" quality, and is frequently substituted for "Fourth" quality, or even "B" quality in markets where the buyers do not have sufficient knowledge of window glass grading to enable them to detect the difference.

It may contain any and all the defects found in window glass, except such as will cause excessive breakage.

"C" glass is not subject to rejection or claims on account of defective quality. It always shows a much higher breakage in shipment than glass of the better qualities.

All 26-oz., 29-oz., 34-oz., and 39-oz. or 3/16" glass produced by us is known to the trade and sold as "Crystal Sheet."

The 26-oz. and 29-oz. glass is produced in "A" or "B" quality only.

RULES FOR GRADING HEAVY SHEET WINDOW GLASS OR "CRYSTAL SHEET":

"Heavy Sheet Window Glass Glazing Quality"

"*The same specifications for selecting provided for A quality single strength and double strength glass shall apply.*"

"Factory Run Quality"

"*This quality is the run of glass as produced by the factory. It may contain glass of very good quality and some glass of very ordinary quality. However, the glass that contains heavy cords, lines or strings over the entire surface, raised blisters, cap strings, stones or batch particles causing a rough surface, or depression, or having its surface covered with heavy burns, wrinkles, deep scratches or stone, shall not be included in this quality.*"

The terms used by us to designate the qualities of this glass have been changed. The cut sizes are now sold only in "Glazing" quality, which is the best quality, and "Commercial" quality, which is the next best quality. The latter embraces glass of all qualities as produced, without selection, except that glass containing very large or very many disfiguring

defects, such as those described under the heading, "Factory Run Quality," is culled out as "off-quality" glass and sold as "OB" quality.

Stock sheets are sold as "Selected Quality Stock Sheets." This includes the sheets of glass of all qualities just as produced, except those containing so many or such large defects, as would render it impossible to cut up the sheets to advantage. These poor quality sheets are set aside and sold as "OB" quality stock sheets, at materially lower prices than the "Selected Quality Stock Sheets."

"Table 1—Tolerances in Thickness and Average Weight of Clear Window Glass."

	Thickness in inches		Number of lights per inch		Average weight in ounces per sq. ft.
	Min.	Max.	Min.	Max.	
Single Strength	.080	.100	10.5	12.0	18.5
Double Strength	.111	.125	8.0	9.0	24.5
26-*oz. Glass*	.125	.135	7.5	8.0	26.0
29-*oz. Glass*	.135	.148	6.5	7.0	29.0
34-*oz. Heavy Glass*	.150	.175	6.0	6.5	34.0
39-*oz. Heavy Glass*	.176	.205	5.0	5.5	39.0
Microscopic Slides	.038	.045	22 *to* 26		9
Lantern Slides	.050	.055	18 *to* 20		11
Photo Dry Plates	.062	.071	14 *to* 16		14
X-Ray Plates	.071	.080	12½ *to* 14		16
16-*oz. Picture*	.071	.080	12½ *to* 14		16

Glass that is slightly thicker than the maximum specified for that strength is always accepted as within the specification, unless it is so much thicker that it is not suitable for the purpose for which it is to be used. A purchaser, however, is not obliged to accept glass that is appreciably thinner than the minimum allowed for that strength.

As a rule, the thickness is judged by the thickness of all the glass in the box, and should not be rejected because a few lights, or parts of lights, are either above or below the range of thicknesses allowed. Mathematical exactness cannot be secured, and should not be demanded.

"Tolerances in Thickness in Individual Sheets"

"*Thickness of individual sheets shall not vary more than ½ of the total variation allowed for that particular strength of glass as shown in Table* 1 (*page* 95) *for sizes up to* 50 *united inches. For larger sizes variations in thickness may be equal to the tolerance allowed for that class.*"

"Sizes Obtainable" (*U. S. Govt. Specifications*)

"*The maximum dimensions recommended are:*

	Width in inches	Length in inches
For Single Strength	40	50
For Double Strength	60	80
For Heavy Sheet	66	90

Single strength glass is made up to 54 inches in length, but we do not take orders for sizes in this thickness larger than 84 united inches. Nor do we take orders for heavy sheet glass in sizes larger than 54 x 80.

"Dimensions"

"*Glass must be cut to dimensions ordered with an allowable tolerance of 1/32" per 1/8" of thickness.*"

"Flatness"

"*All clear window glass shall be relatively flat. Slight curvature, provided it is regular, will be allowed, but the maximum deformation or bow shall not make an arc higher than* 0.5% *of the length of the sheet. Reverse curve or crooked glass is not allowable.*"

Since the above was published we have developed a new process of flattening, which enables us to produce window glass that is absolutely flat from any commercial or practical standpoint. We guarantee this new-process-flattened glass to be as flat as any window glass made by any other process.

This new process also anneals the glass better than the old process, which makes it softer to cut and less liable to break in handling than the glass flattened and annealed by the old methods.

"GLAZING"

"*Window glass should ALWAYS be glazed with the convex side out.*"

The above Specification was drawn when practically all window glass was bowed, but now the greater portion of all window glass produced is flat.

The glazing is one of the most important factors in the appearance of the glass. All window glass, whether bowed or flat, and irrespective of the process by which it is made, has one side that presents a better appearance when glazed to the outside. In the case of bowed glass, it is the convex side. When so glazed, such glass not only looks better, but it will withstand greater wind pressure and concussion shocks than if glazed with the concave side out.

From the standpoint of putting the glass into the sash, flat glass can be glazed with either side out; but from the standpoint of the appearance of the glass in the sash, it is just as important to glaze it with the proper side out as it is when glazing bowed glass. In glazing flat glass, the side on which the glass was cut should be glazed to the outside, as all glass is usually cut on the best surface.

To distinguish on which side the glass is cut, it is necessary to examine carefully the edges of the glass. The edge of the surface on which the glass was cut will have a slightly nicked or roughened appearance, made by the cutting tool, while the under part of the edge will show a slightly wavy appearance caused by breaking the glass apart.

If the windows of a house glazed with window glass are viewed from the outside, and present a smooth, lustrous appearance, and show clear, well defined images of objects reflected in them, one may be sure they have been glazed with the proper side out. But if they present a rough, battered appearance, and distort the images of objects reflected in them, they have been glazed with the wrong side out. Of course, glass that contains humps and depressions on its surface will not reflect properly, no matter which side is glazed to the outside.

In the framing of pictures it is also very important that the better side of the glass should be framed to the outside. Otherwise it will interfere with a proper view of the picture, and portions of it will appear distorted.

All window glass, no matter by what process it is made, has a "grain" that extends in the direction the glass was drawn. Ordinarily, in glazing, this "grain" should be vertical in the sash or frame, as the glass presents a much better appearance when viewed in a reflected light if so glazed. But when glazing sash to be used in automobiles, railroad coaches, or other vehicles, the "grain" should be horizontal in the sash. When so glazed the view from the vehicle is clearer and freer from distortion than when the "grain" is vertical in the sash. When

ordering glass for vehicles, the dimension that is to extend horizontally in the sash should be specified first, and the vertical dimension last, in order that the glass may be cut accordingly.

STRENGTH OF "THE BEST GLASS"

In order to produce a grade of window glass that would be justly entitled to be called "The Best Glass," judged from every standpoint, the American Window Glass Company used the results of a very large number of scientific and practical tests of numerous kinds of glass. Those tests include the following:

Tensile strength; elasticity by bending and torsion; strength of glass in frames to show its resistance to impact, to slow loading at the center, and to uniform loading over the entire area; annealing; extent of expansion by heat; determination of the modulus of rupture by bending, impact, loading, and torsion; chemical composition; and others.

Many of these tests were made by the United States Bureau of Standards which tested approximately 5000 samples of glazing glass of various types and makes for strength with transverse load, and impact to determine the modulus of rupture. Several thousand samples were also tested for various properties in the laboratories of the University of Pittsburgh and other testing laboratories.

MODULUS OF RUPTURE

Of all the tests made, that of the modulus of rupture is the most important to the glass user. The technical term "modulus of rupture" is "the measure of the force which must be applied in order to produce rupture," *i.e.*, to break the glass, when subjected to tests for bending, impact, loading, or torsion. Its value is expressed in pounds per square inch and signifies the average load required to produce the rupture under any of the four tests above mentioned.

RESULTS

Those tests demonstrated the superiority of the American Window Glass Company's brand "The Best Glass" in the matter of tensile strength and modulus of rupture over any other window glass, plate glass, or rolled glass.

Furthermore its higher modulus of rupture proves that "The Best Glass" will withstand greater wind pressure than any other glass.

For the benefit of those who desire precise information as to the modulus of rupture of our glass, we submit a copy of a diagram (Fig. 1) prepared by the *United States Bureau of Standards, Department of Commerce, showing the modulus of rupture of

*Presented by A. E. Williams, of the Bureau of Standards, before the Glass Division, American Ceramic Society, Pittsburgh Meeting, February, 1923. By permission of the Director of the Bureau of Standards, Department of Commerce.

various thicknesses of clear window glass and ¼-inch polished plate. This diagram shows the overwhelming superiority of the clear window glass in the matter of modulus of rupture.

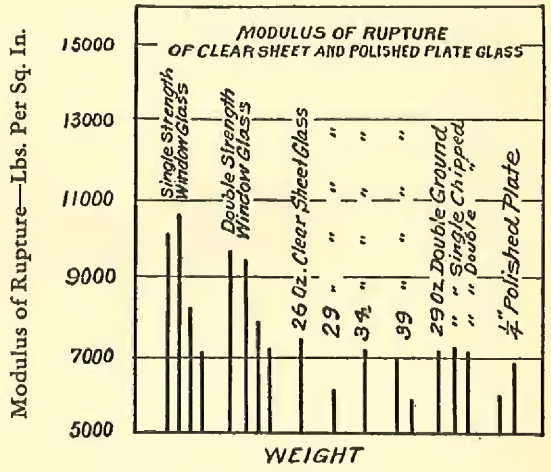


FIG. I

The figures given in the diagram for the modulus of rupture of clear window glass are identical with the figures furnished to the American Window Glass Company by the Bureau of Standards, showing the results of numerous tests conducted by the Bureau of Standards on samples of the American Window Glass Company's glass submitted to the Bureau for

purposes of tests. The results of the tests by the Bureau of Standards on the American Window Glass Company's glass for modulus of rupture were confirmed by similar tests made by other testing laboratories.

The Tensile strength tests of the American Window Glass Company's brand, "The Best Glass," show a tensile strength of 5100 pounds per square inch. Similar tests conducted on other kinds of glass demonstrated that none of them approached the tensile strength of "The Best Glass."

Fourteen Reasons

FOR YOUR SPECIFICATION OF

"The BEST Glass"

1 Our melting furnaces are the largest in the world and produce perfectly melted glass.

2 Our improved mechanical process of drawing and blowing gives our glass greater tensile strength and higher modulus of rupture than any other window glass, plate glass, or rolled glass; consequently, it offers greater resistance to wind pressure.

3 Our latest improvements in our blowing machines enable us to provide absolutely perfect cylinders, which make it possible to secure the best flattening ever obtained.

4 Our new method of flattening gives our glass a perfectly smooth surface, and a brilliant polish, unequalled by any other window glass.

5 Our glass has less wave than any other glass, and consequently, shows less distortion.

6 Our glass is flat; it contains no reverse curves.

7 Our glass is uniform in thickness.

8 Our glass is perfectly annealed and, therefore, does not break as easily as poorly annealed glass.

9 Our glass is washed and thoroughly cleaned in an acid bath, which prevents discoloration and permits ready detection of defects.

10 Our glass cuts perfectly on both sides.

11 Our glass is graded to the highest standard of quality.

12 Our grading is the recognized standard for the United States, and is higher than the foreign standards.

13 Our glass does not break in shipment on account of the uniformity of flatness, well made boxes, great care in packing and skillful loading.

14 Our entire process is conducted on scientific principles.

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